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Sedimentology of early Pliocene sandstones in the south-western Taiwan foreland: Implications for basin physiography in the early stages of collision

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ABSTRACT

This work presents sedimentological observations and interpretations on three detailed sections of the Pliocene Yutengping/Ailiaochiao formations, deposited in the early stages of collision in Taiwan. Seven facies associations record paleoenvironments of deposition ranging from nearshore to lower offshore with a strong influence of tidal reworking, even in shelfal sub-tidal environments, and a pro-delta setting characterized by mass-flows. The association of shallow facies of the upper offshore to lower shoreface with pro-delta turbidite facies sourced in the orogen to the east suggests a peculiar setting in which turbidite deposition occurred below wave base but on the shelf, in water depths of probably less than 100 m. This adds to the examples of "shallow turbidites" increasingly commonly found in foreland basins and challenges the classical view of a "deep" early underfilled foreland basin. Time series analysis on tidal rhythmites allow us to identify a yearly signal in the form of periodic changes of sand-supply, energy and bioturbation that suggests a marked seasonality possibly affecting precipitation and sediment delivery as well as temperature. The Taiwan foreland basin may also present a potentially high-resolution record in shallow sediments of the early installation of monsoonal circulation patterns in east Asia. We confirm partly the paleogeography during the early stages of collision in Taiwan: the Chinese margin displayed a pronounced non-cylindrical geometry with a large basement promontory to the west in place of the modern Taiwan mountain range. Collision in Taiwan may have happened at once along the whole length of the modern mountain range, instead of progressively from north to south as classically considered.

1. Introduction

Foreland basin sediments preserve a unique record of the tectonic and climatic processes that construct and destroy topography during plate collision (Allen et al., 1986). As such their study is fundamental for the understanding of mountain building processes. The foreland basin situated to the west of the Taiwan mountain ranges is of particular interest because it contains a record of the evolution of one of the best known and most studied orogens.

The island of Taiwan is situated on the boundary between the Philippine Sea Plate and the Eurasian Plate and is a textbook example of an arc-continent collision (Ho, 1986; Sibuet and Hsu, 1997; Suppe, 1984). Subduction of the South China Sea as part of the Eurasian Plate (EUR) beneath the Luzon Arc on the Philippine Sea Plate (PSP) has progressively consumed the oceanic crust and the Luzon Arc is presently colliding with the passive margin of Eurasia creating the mountain belt of Taiwan since the Late Miocene (Fig. 1). The obliquity between the passive margin and the Luzon Arc seems to result in a "zippering" effect of progressive closure of the South China Sea towards the south, such that the collision would be older in northern Taiwan than in southern Taiwan. Furthermore, the high rates of convergence (Seno et al., 1993; Yu et al., 1997), high rate of rock uplift and the wet, stormy climate of the sub-tropical typhoon belt combine to produce erosion and sediment yield rates amongst the highest in the world (Dadson et al., 2003). These characteristics make Taiwan one of the world's foremost natural laboratories to study orogenesis and foreland basin development.

The progressive arc-continent collision and its southward propagation has been extensively studied, numerous tectonic studies and models address the collisional process (Barr and Dahlen, 1989; Chemenda et al., 2001; Dahlen and Barr, 1989; Ernst and

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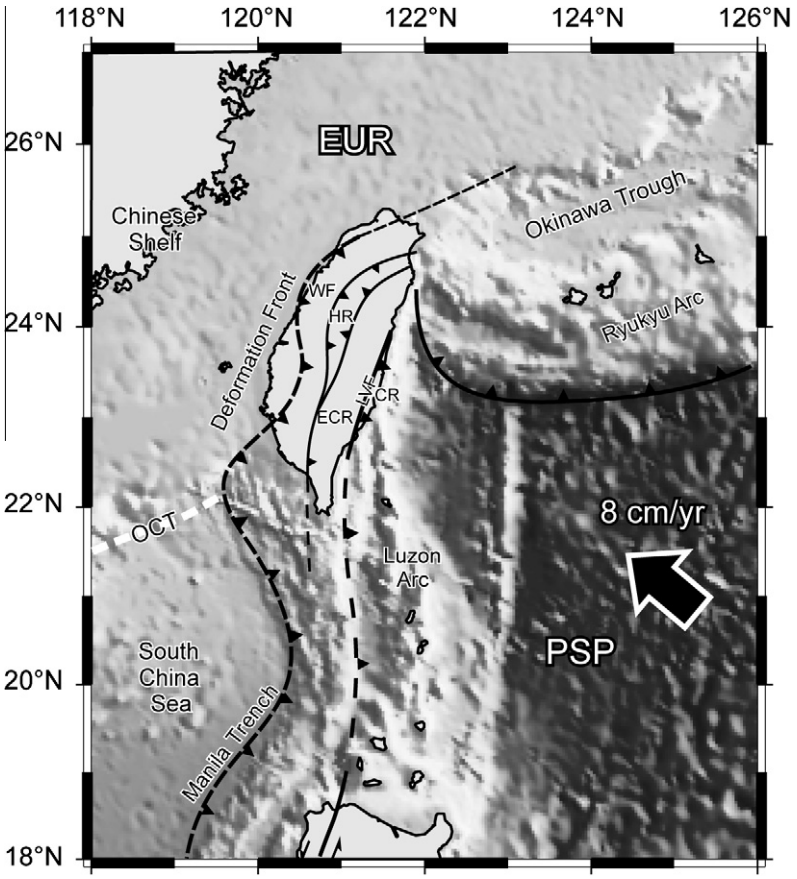

Fig. 1. Geodynamic context of the collision in Taiwan. PSP: Philippine Sea Plate; EUR: Eurasian Plate; WF: western Foothills; HR: Hsüehshan Range; ECR: Eastern Central Range; LVF: Longitudinal Valley Fault; CR: Coastal Range; OCT: Ocean–Continent Transition.

Jahn, 1987; Fuller et al., 2006; Liu et al., 2001; Suppe, 1981, 1984; Wu et al., 1997). The development of the foreland basin as a loading and sedimentation response to the mountain building has also been largely documented (Chen et al., 2001a; Chiang et al., 2004; Covey, 1986; Lin and Watts, 2002; Lin et al., 2003; Simoes and Avouac, 2006; Teng, 1991; Tensi et al., 2006).

However, despite the extensive amount of work done there exists as yet no comprehensive synthesis of the syn-orogenic depositional environments and the associated paleogeography of the basin, and of the sediment transport systems originating in the orogen. It is essential to fill this gap in knowledge in order to derive detailed analysis of the spatio-temporal evolution of the subsidence and sedimentary fill and its relationship to tectonic and denudational events in the orogenic belt. It is a long-term objective to re-evaluate Taiwan's collisional paleogeography in the light of new data in order to render tectonic and geomorphic reconstitutions possible. The present paper represents a first analysis of three sections measured in detail in south-western Taiwan that provide information on the early Pliocene paleogeography and dynamics of the sedimentary system at the beginning of the collision.

The foreland basin of Taiwan is one of the first basins where a "foreland sequence" with a underfilled to overfilled transition was identified (Covey, 1986). By studying the Plio-Pleistocene deposits of the western Taiwan foreland basin from north to south, Covey (1986) proposed an evolutionary model of a foreland basin in relation with the growth stage of the adjacent orogen comprising an initial transgressive stage at the initation of foreland basin subsidence, a deep water stage when subsidence exceeded sediment input from the growing orogen, and a third steady-state shallow water to fluvial stage when the foredeep was at steady state and sediment supply by-pass the plain to outer deeper environments. This model was influenced by (1) the emerging paradigm of Taiwan's southward propagation (Suppe, 1981), and (2) the observation of the current sub-marine setting south of Taiwan where deep sea fans actively form on the continental slope to basin settings in front of the accretionary wedge. It is crucial for the paleogeography of Taiwan to search for indications of paleo-water depth in the early stages of the collision in order to better understand the tectonic setting at that time. This has important implications for the general understanding of foreland basin development.

The objective of this paper is to present a detailed analysis of the facies encountered in the studied sections and their interpretation in terms of paleoenvironments in the Western Foreland Basin. We then discuss the physiographic implications for the early stages of collision.

2. Geological setting

2.1. The Taiwan orogen

The Taiwan orogen developed on the Chinese continental margin in response to the convergence between the EUR and the PSP (Ho, 1986; Suppe, 1980). The convergence velocity of the PSP relative to the EUR plate is of the order of 7–8 cm y^{-1} (Seno et al., 1993; Yu et al., 1997). The general structure of the range is composed of several units (Fig. 1). To the east, the "Coastal Range" (CR) represents the part of the Luzon Arc that is presently colliding with the Chinese continental margin. It is constituted by Miocene volcanic rocks and intra-arc flysch basins. The suture zone separating the CR from the Chinese continental margin is represented by the "Longitudinal Valley" (LV), a narrow depression underlain by